

A Landscape Assessment of the Catskill/Delaware Watersheds 1975-1998

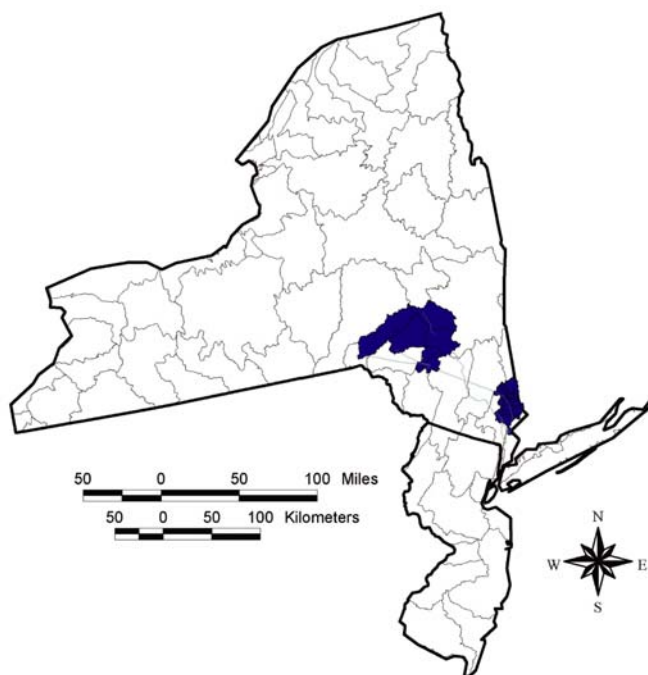
New York City's Water Supply Watersheds



A Landscape Assessment of the Catskill/Delaware Watersheds 1975-1998

New York City's Water Supply Watersheds

M.H. Mehaffey¹, M.S. Nash¹, T.G. Wade², C.M. Edmonds¹,
D.W. Ebert¹, K.B. Jones¹, and A. Rager³



¹ U.S. Environmental Protection Agency, Office of Research and Development, National Exposure Research Laboratory, Environmental Sciences Division, Las Vegas, Nevada

² U.S. Environmental Protection Agency, Office of Research and Development, National Exposure Research Laboratory, Environmental Sciences Division (Research Triangle Park)

³ Lockheed Martin Environmental Services, Las Vegas, Nevada

Notice

The U.S. Environmental Protection Agency (EPA), through its Office of Research and Development (ORD), funded and performed the research described here. It has been subjected to the Agency's peer review process and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation by EPA for use.

Contents

| | Page |
|------------------------------------------|-------|
| Notice | i |
| Tables | v |
| Figure | vii |
| Abbreviations | x |
| Acknowledgments | xi |
| Executive Summary | xii |
| Chapter 1. Introduction | 1 |
| Objectives | 1 |
| Overview | 1 |
| Layout | 4 |
| Chapter 2. The Biophysical Setting | 5 |
| Land Cover and Topography | 5 |
| Streams | 9 |
| Watersheds | 11 |
| Chapter 3. Methodology | 14 |
| Regional Classification | 14 |
| Catskill/Delaware Classification | 15 |
| EPA-Delineated Watersheds | 15 |
| Landscape Metrics | 16 |
| Surface Water Quality Measurements | 18 |
| Data Evaluation | 19 |
| Data Sources | 19 |
| Data Analyses | 20 |
| Chapter 4. Land Cover/Use | 22 |
| Forest Land Cover | 22 |

Contents (continued)

| | Page |
|----------------------------------------------------|------|
| Agriculture | 23 |
| Agriculture on Erodible Soils | 24 |
| Roads | 26 |
| Population Growth and Urban Development | 28 |
| Human Use Index | 30 |
| Riparian Land Cover/Use | 31 |
| Landscape Summary | 33 |
| Chapter 5. Landscape Change | 34 |
| Change in the Watershed | 34 |
| Change in the Riparian Buffer | 37 |
| Landscape Change Summary | 39 |
| Chapter 6. Surface Water Quality | 40 |
| Spatial Variation | 40 |
| Temporal Variation | 40 |
| Rainfall and Discharge | 43 |
| Total Nitrogen | 45 |
| Total Phosphorus | 45 |
| Fecal Coliform Bacteria | 45 |
| Water Quality Summary | 46 |
| Chapter 7. Landscape and Water Relationships | 47 |
| Regression Models | 47 |
| Total Nitrogen | 47 |
| Total Phosphorus | 49 |
| Fecal Coliform Bacteria | 49 |
| Model Application | 49 |
| Trends in Water and Landscape | 53 |
| Relationship Summary | 53 |

Contents (continued)

| | Page |
|-----------------------------------------------------------|------|
| Chapter 8. Conclusion | 56 |
| Summary | 56 |
| Recommendations | 58 |
| Appendices | |
| A. Methodology Details | 60 |
| Image Classification | 60 |
| Accuracy Assessment | 62 |
| Watershed Delineation | 65 |
| Landscape Metrics | 65 |
| Statistical Analyses | 67 |
| B. Regional Watershed Landscape Metrics | 68 |
| C. Catskill/Delaware Subwatershed Landscape Metrics | 76 |
| D. Catskill/Delaware Water Quality Site Data | 88 |
| Glossary | 106 |
| References | 113 |
| Books for Interested Readers | 117 |

Tables

| | Page |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 2.1. Region 2 Hydrologic Unit Numbers and Names. (HUCs in blue surround the Catskill/Delaware watersheds) | 11 |
| 2.2. Catskill/Delaware Subwatershed Names with Numbers Corresponding to Figure 2.8 | 13 |
| 3.1. Aggregation of the National Land Cover Data (NLCD) Region 2 Land Cover Classes | 14 |
| 3.2. Drinking and Ambient Water Quality Standards for Nitrogen, Phosphorus, and Fecal Coliform Bacteria | 18 |
| 4.1. Late 1990s Land cover/use in the Catskill/Delaware Subwatersheds | 23 |
| 4.2. Descriptive Statistics for the Catskill/Delaware Subwatersheds and Two Riparian Buffers | 33 |
| 5.1. Change in Agriculture Metrics in the Catskill/Delaware Subwatersheds (mid-1970s to late 1990s) | 34 |
| 5.2. Land Cover Change (mid-1970s to late 1990s) in the Catskill/Delaware Subwatersheds | 36 |
| 5.3. Total Land Cover, Agriculture (Ag), and Forest Change in the Catskill/Delaware Watersheds Riparian Buffer (60 m) from mid-1970s to late 1990s | 37 |
| 6.1. Mean and Median Total Nitrogen, Total Phosphorus, Fecal Coliform Bacteria (1994-1998) in Surface Water Sample Sites Upstream and Downstream of Sewage Treatment Plants in the Catskill/Delaware Watersheds | 43 |
| 6.2. Descriptive Statistics for Precipitation (1987-1998), Discharge (1987-1998), Total Nitrogen (1990-1998), Total Phosphorus (1990-1998), and Fecal Coliform Bacteria (1987-1998) at Select Surface Water Sample Sties in the Catskill/Delaware Watersheds .. | 44 |
| 7.1. Regression Model Estimates (β), Partial R^2 and Model R^2 for Landscape Metrics for Total Nitrogen, Total Phosphorus, and Fecal Coliform Bacteria for the mid-1980s, early 1990s, and late 1990s | 48 |
| 7.2. Average Observed Total Nitrogen (TN), Total Phosphorus (TP), and Fecal Coliform Bacteria (FC) from Four Surface Water Sample Sites not used in the Landscape Model Compared with Model Predicted Upper and Lower 95% Confidence Interval (CI) Values from Subwatersheds having Similar Land Cover Percentages | 51 |
| 7.3. Trends in Total Nitrogen (1990-1998), Total Phosphorus (1990-1998), Fecal Coliform Bacteria (1987-1998) and Landscape Metrics (1987-1998) in 32 Catskill/Delaware Subwatersheds | 54 |

Tables (continued)

| | Page |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 7.4. Trends in Total Nitrogen (1990-1998), Total Phosphorus (1990-1998), Fecal Coliform Bacteria(1987-1998) and Riparian Landscape Metrics (1987-1998) in 32 Catskill/Delaware Subwatersheds | 55 |
| Appendices | |
| A-1. Images Used in Land Cover Classifications of Catskill/Delaware Watersheds | 60 |
| A-2. Catskill/Delaware Watersheds Land Cover Area (ha) 30-m versus 60-m resolution | 61 |
| A-3. Calculated and Actual Number of Samples Used in the Accuracy Assessment | 62 |
| A-4. Mid-1970s Classification Error Matrix | 63 |
| A-5. Mid-1980s Classification Error Matrix. | 63 |
| A-6. Early 1990s Classification Error Matrix | 64 |
| A-7. Late 1990s Classification Error Matrix | 64 |
| B-1. Land Cover/Use (early 1990s) for the EPA Region 2, 8-Digit Watersheds | 68 |
| B-2. Riparian Buffer (60m) Land Cover/Use (early 1990s) for the EPA Region 2, 8-Digit Watersheds | 72 |
| C-1. Land Cover/Use (late 1990s) for NYCDEP Subwatersheds | 76 |
| C-2. Land Cover/Use (late 1990s) for NYCDEP Subwatershed | 80 |
| C-3. Land Cover/Use (late 1990s) for NYCDEP Subwatershed Riparian Buffers | 84 |
| D-1. Water Quality Site (NYCDEP) Locations, Universal Transverse Mercator, Zone 18..... | 88 |
| D-2. Waste Treatment Plant Site (NYCDEP) Locations, Universal Transverse Mercator, Zone 18..... | 89 |
| D-3. Site Locations for Water Quality, Discharge, and Precipitation, Universal Transverse Mercator, Zone 18..... | 90 |
| D-4. Descriptive Statistics for 32 Water Quality Sites in the Catskill/Delaware Watersheds | 91 |

Figures

| | Page |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 1.1. The locations of Region 2 (states of New York and New Jersey) and the New York City water supply watersheds. | 1 |
| 1.2. The percent of impaired waterbodies within the Region 2 watersheds on the 303d list. | 2 |
| 1.3. The New York City water supply system. | 3 |
| 2.1. Shaded relief map of Region 2 and location of the Catskill/Delaware watersheds. | 5 |
| 2.2. Average percent soil total organic matter across Region 2. | 6 |
| 2.3. Land cover/use in (a) Region 2 and (b) the Catskill/Delaware watersheds. | 7 |
| 2.4. Shaded relief map of the Catskill/Delaware watersheds. | 8 |
| 2.5. Streams and water bodies in the six hydrologic units surrounding the Catskill/Delaware watersheds. | 9 |
| 2.6. Streams and waterbodies in the Catskill/Delaware watersheds. | 10 |
| 2.7. Watershed boundaries within Region 2. | 11 |
| 2.8. Catskill/Delaware watersheds and subwatersheds. | 12 |
| 3.1. Illustration of differential light reflectance properties for sediments suspended in water and land surfaces over a portion of Long Island Sound. | 14 |
| 3.2. Catskill/Delaware watersheds and a subset of EPA-delineated subwatersheds. | 15 |
| 3.2. An illustration of the GIS clipping process used to calculate percentages of land cover/use within a Catskill/Delaware watershed boundary. | 16 |
| 3.3. An illustration of the types of maps that appear in the following report. | 17 |
| 3.4. Location of the rainfall, discharge and water quality sample sites used to examine temporal variation in the Catskill/Delaware watersheds. | 20 |
| 4.1. Percentage of forested land cover in (a) Region 2 watersheds and (b) the Catskill/Delaware subwatersheds. | 22 |
| 4.2. Percentage of agricultural land cover in Region 2 watersheds. | 23 |
| 4.3. Percentage of agricultural land cover in Catskill/Delaware watersheds | 24 |
| 4.4. Average soil erodibility factor (k-factor) for Region 2. | 24 |

Figures (continued)

| | Page |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 4.5. Percentage of the Catskill/Delaware subwatersheds with agricultural land use on (a) slopes > 5% or (b) soils with k-factor values >0.3. | 25 |
| 4.6. Road density in Region 2. | 26 |
| 4.7. Road density in the Catskill/Delaware subwatersheds. | 27 |
| 4.8. Roads crossing streams in the Catskill/Delaware subwatersheds. | 27 |
| 4.9. Percentage of urban land use in Region 2 watersheds. | 28 |
| 4.10. Population change within the Catskill/Delaware watersheds. | 29 |
| 4.11. Percentage of urban land use in the Catskill/Delaware watersheds. | 29 |
| 4.12. Percentage of watershed in human land use in Region 2. | 30 |
| 4.13. Percentage of the Catskill/Delaware subwatersheds in human land use. | 30 |
| 4.14. Percentage of the riparian buffer in forest, agriculture, wetland, barren, and urban land cover/use in Region 2 watersheds. | 31 |
| 4.15. Percentage of the riparian buffer in forest, agriculture, urban, and barren land cover/use in the Catskill/Delaware subwatersheds. | 32 |
| 5.1. Change in percent (a) forest, (b) urban, (c) agriculture, and (d) barren in the Catskill/Delaware watersheds from mid-1970s to late 1990s. | 35 |
| 5.2. Vegetation change between forest cover and agricultural or urban land use from mid-1970s to late 1990s in the Catskill/Delaware watersheds. | 36 |
| 5.3. Change in the riparian buffer (60 m) percent (a) forest, (b) urban, (c) agriculture, and (d) barren in the Catskill/Delaware watersheds from mid-1970s to late 1990s. | 38 |
| 5.4. Net vegetation change in the riparian buffer between forest cover and agricultural land use in the Catskill/Delaware subwatersheds from mid-1970s to late 1990s. | 38 |
| 6.1. Median (1994 - 1998) (a) fecal coliform bacteria, (b) total nitrogen, and (c) total phosphorous within the Catskill/Delaware subwatersheds. | 41 |
| 6.2. The upstream (WSPA) and downstream (WSPB) of the Walton Sewage Treatment Plant (WSPA) surface water sample site (a) location and median total nitrogen and (b) average monthly total nitrogen from 1994 to 1998. | 42 |
| 7.1. Predicted average (late 1990s) (a) fecal coliform bacteria, (b) total nitrogen, and (c) total phosphorus within the Catskill/Delaware subwatersheds based on the regression model. | 50 |

Figures (continued)

| | Page |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 7.2. Average observed total nitrogen (TN), total phosphorus (TP), and fecal coliform bacteria (FC) from four surface water sample sites not used in the landscape models | 52 |
| 8.1. Catskill/Delaware subwatersheds having landscape metrics associated with water quality degradation. | 57 |

Appendices

| | |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| D-1. Average monthly (1987-1998) discharge and (a) precipitation, (b) total nitrogen, (c) total phosphorus, and (d) fecal coliforms at the Cannonsville water quality trend sites. | 94 |
| D-2. Average monthly (a) total nitrogen (1990-1998), (b) total phosphorus (1990-1998), and (c) fecal coliforms (1987-1998) at the Cannonsville water quality trend site. | 95 |
| D-3. Average monthly (1987-1998) discharge and (a) precipitation, (b) total nitrogen, (c) total phosphorus, and (d) fecal coliforms at the Ashokan water quality trend sites. | 96 |
| D-4. Average monthly (a) total nitrogen (1990-1998), (b) total phosphorus (1990-1998), and (c) fecal coliforms (1987-1998) at the Ashokan water quality trend site. | 97 |
| D-5. Average monthly (1987-1998) discharge and (a) precipitation, (b) total nitrogen, (c) total phosphorus, and (d) fecal coliforms at the Neversink water quality trend sites. | 98 |
| D-6. Average monthly (a) total nitrogen (1990-1998), (b) total phosphorus (1990-1998), and (c) fecal coliforms (1987-1998) at the Neversink water quality trend site. | 99 |
| D-7. Average monthly (1987-1998) discharge and (a) precipitation, (b) total nitrogen, (c) total phosphorus, and (d) fecal coliforms at the Pepacton water quality trend sites. | 100 |
| D-8. Average monthly (a) total nitrogen (1990-1998), (b) total phosphorus (1990-1998), and (c) fecal coliforms (1987-1998) at the Pepacton water quality trend site. | 101 |
| D-9. Average monthly (1987-1998) discharge and (a) precipitation, (b) total nitrogen, (c) total phosphorus, and (d) fecal coliforms at the Rondout water quality trend sites. | 102 |
| D-10. Average monthly (a) total nitrogen (1990-1998), (b) total phosphorus (1990-1998), and (c) fecal coliforms (1987-1998) at the Rondout water quality trend site. | 103 |
| D-11. Average monthly (1987-1998) discharge and (a) precipitation, (b) total nitrogen, (c) total phosphorus, and (d) fecal coliforms at the Schoharie water quality trend sites. | 104 |
| D-12. Average monthly (a) total nitrogen (1990-1998), (b) total phosphorus (1990-1998), and (c) fecal coliforms (1987-1998) at the Schoharie water quality trend site. | 105 |

Abbreviations

| | |
|------------------------------------------------------------------|----------------------------|
| ATtILA - Analytical Tools Interface for Landscape Assessments | % - percent |
| β - Magnitude of the Coefficients | CFU - colony forming units |
| BMP - best management practice | cm - centimeter |
| CI - confidence interval | ft - foot |
| CD - Catskill/Delaware | g - grams |
| DEM - digital elevation model | ha - hectare |
| DLG - digital land graph | in - inch |
| EPA - U.S. Environmental Protection Agency | km - kilometer |
| EPIC - Environmental Photographic Interpretation Center | L - liter |
| EROS - Earth Resources Observation Systems | m - meter |
| FAD - filtration avoidance determination | μ g - microgram |
| FC - fecal coliform bacteria | mi - mile |
| GIS - geographic information system | ml - milliliter |
| HUC - hydrologic unit code | mg - milligram |
| LEB - Landscape Ecology Branch | mm - millimeter |
| MCL - water maximum contaminant levels | sec - second |
| MOA - Memorandum of Agreement | |
| MRLC - Multi-Resolution Land Characteristics | |
| MSS - multispectral scanner | |
| N-index - natural vegetation index | |
| NALC - North American Landscape Characterization | |
| NAPP - National Aerial Photography Program | |
| NDVI - normalized-difference vegetation index | |
| NERL - National Exposure Research Laboratory | |
| NHAP - National High Altitude Photography | |
| NLCD - National Land Cover Data | |
| NRCS - Natural Resource Conservation Service | |
| NYCDEP - New York City Department of Environmental Protection | |
| NYSDEC - New York State Department of Environmental Conservation | |
| ORD - Office of Research and Development | |
| Partial R^2 - partial coefficient of multiple determination | |
| QA - quality assurance | |
| R^2 - coefficient of multiple determination | |
| RF3 - River Reach File, Version 3 | |
| STATSGO - State Soil Geographic Data Base | |
| SSURGO - Soil Survey Geographic Data Base | |
| TM - Thematic Mapper | |
| TMDL - total maximum daily load | |
| TN - total nitrogen | |
| TP - total phosphorus | |
| U-Index - human use index | |
| USDA - United States Department of Agriculture | |
| USGS - United States Geological Survey | |
| VIF - variance inflation factor | |
| WSPA - Walton Sewage Treatment Plant (upstream) | |
| WSPB - Walton Sewage Treatment Plant (downstream) | |

Acknowledgments

The authors would like to thank all the people who have participated in the creation of this study. Special thanks goes to the staff of the New York City Department of Environmental Protection (NYCDEP). In particular, Michael Principe who was willing to consider our proposed study and authorize the use of the NYCDEP water chemistry data; Barbara Dibler who willing shared her knowledge of GIS, the watershed, and its community whenever we visited; and David Lipsky who provided and compiled editorial comments which made this report more complete. We thank the Delaware County U.S. Department of Agriculture (USDA) Farm Service Association and its staff for sharing their collective knowledge of the farming practices within the watershed. We also send our thanks to Jeff Gratz and New York City Watershed Team members who provided input that helped in the completion of this report. In addition, we thank David Braun and Colin Apse from the Nature Conservancy, Neversink River Program, who provided extensive editorial comments which strengthened this final product. A special thanks also to Donna Sutton from Lockheed Martin Technical Services who provided the final polish with her technical edits. Last, but certainly not least, we would like to thank all the staff of the Landscape Ecology Branch, our family, and friends, many of whom provided invaluable assistance in the production, assessment, processing, analyzing, and editing of this report. Without the above mentioned people this study could not have been completed.

Executive Summary

Together the six reservoirs located in the Catskill/Delaware watersheds supply 90% of New York City's drinking water. The 4,100 km² (1,583 mi²) Catskill/Delaware watersheds are located in the southeast corner of New York State, 160 km (100 mi) northwest of New York City. The study summarized here provides (1) regional and local scale data that will assist land managers, policy makers, and the general public in making informed decisions on environmental and water resource issues; and (2) data analyses that help direct future land cover and land use practices critical to maintaining water quality.

The first chapter of the report gives an overview of regional and watershed land cover allowing the reader to compare environmental conditions of the Catskill/Delaware water supply watersheds to other areas within Region 2. The remainder of this report takes a closer look at landscape change, water quality, and land use relationships and trends through time in the Catskill/Delaware watersheds.

There are six watersheds contained within the CD water supply area, each ending in a manmade reservoir. The topography of the area is diverse and, except for the Adirondacks to the north, has the greatest elevation in the state. The landscape of the Catskill/Delaware watersheds has changed little in the past two decades, with forest cover remaining the dominant vegetation in the area. Historically, the Catskill/Delaware watersheds have been dominated by northern hardwoods, including maple, birch, and beech trees. Much of the area was logged prior to the mid-1800s. Today, secondary forest consisting of evergreen and deciduous species covers about 90% of the watersheds. Human use ranges from 0 to 40% of the subwatershed areas, and averages 11% across the entire Catskill/Delaware watersheds. Compared to other watersheds within Region 2, such as those near the Great Lakes and Long Island, which have human use percentages reaching 80%, the environmental disturbance within the Catskill/Delaware watersheds is low.

Population has increased by only 15% from 53 to 64 thousand people between 1970 and 1995.

However, as a result of topographic constraints, the

majority (90%) of urban and agriculture land use is located within a 120-m (395-ft) riparian buffer. The highest amount of human use is located in the less rugged terrain of the northwest and the lowest is in the southeast watersheds.

Only one reservoir, the Cannonsville, exceeds State and Federal total maximum daily load (TMDL) standards for phosphorus. However, all six reservoirs and one stream are currently included on the State 303d list for sediment, phosphorus, or pathogens levels. At lower levels, nitrogen and phosphorus do not pose a threat to either human health or aquatic habitat. However, when the nutrient levels are enriched, eutrophication can occur resulting in algal blooms. Excessive algal growth can disrupt stream habitat, deplete oxygen levels, and raise turbidity, odor, and color to unacceptable levels. When present in the water, fecal coliforms indicate contamination by warm-blooded animal waste. Human health is affected by other pathogens, which may be excreted along with the fecal coliforms, such as bacteria, protozoa, and viruses. In many cases, excessive nutrient and fecal coliform levels are the result of nonpoint pollution related to land use and land use practices. Modifying these practices can improve water quality conditions. However, in a few cases spikes can result from unexpected sources such as migratory bird populations or accidental spills.

Total nitrogen, phosphorus, and fecal coliform data were selected for study because of public concern about the 303d listing of the water supply reservoirs for nutrients and pathogens and the potential linkages to land use. Like patterns of human use, average water quality measurements of nitrogen, phosphorus, and fecal coliforms are highest in the northwest and lowest in the southeast of the Catskill/Delaware watersheds. Monthly averages of nitrogen, phosphorus, and fecal coliform, in general, do not exceed ambient water quality standards. However, in watersheds having the most human use, a few water sampling sites have median and average values that approach or slightly exceed current standards. These are most frequently at sites downstream of sewage treatment facilities.

Multiple regression analysis is used to examine the relationship of landscape metrics to surface water concentrations of total nitrogen, total phosphorus, and fecal coliform. The percentages of agriculture and urban development in the subwatersheds are significantly related to all three water quality measurements. Agriculture is the dominant human use in the subwatersheds and riparian buffer. Results from the regression analyses suggest that as the percentages of agriculture and urban development increase, surface water concentrations of total nitrogen, total phosphorus, and fecal coliform can also be expected to increase. Three other metrics having a significant relationship to water quality parameters, but explaining only a small portion of overall variability in water quality, are percent bare ground, percent agriculture on steep slopes, and percent agriculture on erodible soils within the subwatersheds. Therefore, increases in the percentage of these land uses associated with increased erosion may result in elevating total nitrogen, total phosphorus, and fecal coliform levels in surface water.

Release of agricultural fields from farming has returned a small percentage of land to secondary growth forest. During the past two decades this change has resulted in a 2% net increase in forest cover. The effect of this land cover change is evident in the decreasing contribution of agriculture to total nitrogen concentrations within the surface water from 1987 to 1998. The direction of change in surface water and landscape condition indicates that those measurements of land use significant to single date comparisons are also important to trends in time.

These results suggest targeting the farms in a subwatershed having high percentages of land use types associated with water quality degradation may achieve greater overall pollution reduction to the water supply than random areawide enrollment in farm management programs. Selecting Best Management Programs to initiate would then depend on which pollutant is of highest priority for that subwatershed. Farmers within subwatersheds nearest to the reservoirs and having low stream

density should be encouraged to preserve wetland and riparian areas through enrollment in wetland reserve and forest easement programs. These efforts would help buffer streams and reservoirs from nonpoint pollution via runoff from barnyards, pastures, and crop fields.

Another key component to determining water quality is the percent of urban land use within the subwatershed. The current regulations proposed in the Memorandum of Agreement for improving existing treatment plant performance and restricting new waste treatment plants should help reduce point source inputs in the Catskill/Delaware watersheds. However, in addition to waste treatment plant inputs, high percentages of impervious surfaces have increased discharge rates, sedimentation, and pollutant runoff in a number of the subwatersheds. An urban planning program that helps landowners develop best management practices for golf courses, parks, backyard gardens, and lawns could help address some of the current impacts. Offsetting future land uses will most likely require increasing the percentage of forest cover, particularly in the riparian buffer. One way to help promote more riparian forest is by increasing the setbacks requirements for human use from 30 to 60 or 120 m.

Balancing water quality protection and economic growth requires a great deal of thought, coordination, and cooperation. As demonstrated by the results of this study, human use of the landscape has direct consequences on water quality resources. Even changes as small as 2% can have an effect. Whether or not the change is beneficial to the quality of water supplied by the Catskill/Delaware watersheds, rests on the choices made by those living in the area. Economic and social incentives which encourage forestry, agriculture and urban planning and management for specific subwatershed needs within the Catskill/Delaware watersheds can help facilitate the continued success of long-term watershed management plans set forth in the Memorandum of Agreement.